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Contractor Report ARAED-CR-95009

# COMPRESSION STRENGTH AND DROP TEST PERFORMANCE OF XM232 CASE ASSEMBLIES

S. Dyer, A. Faburada, K. Gallavan, and M. Hoogendyk  
ARMTEC Defense Production Co.  
85-901 Avenue 53  
Coachella, CA 92236

P. Hui and L. Chang  
Project Engineers  
ARDEC

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## **OBJECTIVE**

The objectives of this study were:

- To determine if the XM232 case, as currently manufactured, meets radial and axial compression strength requirements proposed by the French for the JBMOU.
- To determine if a "special production" light weight type XM232 case meets rough handling requirements for straight and angle drop tests.

## **SCOPE**

This evaluation involved radial and axial compression testing of assembled XM232 cases that had been filled with rice to simulate propellant. In addition, light weight XM232 cases were filled with a rice/gravel mixture, assembled, and drop tested.

## **EXPERIMENTAL**

### **Equipment**

Instron test apparatus with 8 in. diameter flat plate fixtures for compression testing

Electronic balance

### **Materials**

Fifty XM232 case sets with normal (standard) production weight range

Twelve "special production" XM232 case sets with light weight (~84% of normal) bodies and caps

Acetone

Long grain white rice

Rock gravel, ~1/2 x 1/8 in.

## **Case Loading and Assembly**

Fifty-six case sets were loaded with rice and assembled for compression testing (50 normal and 6 light weight). Each of the trimmed case components was weighed and labeled with an identification number. The case body components were then fitted with their respective cores. Next, each case was loaded with 1,850 g (4.1 lb) long grain white rice. The case sidewall was periodically hand tapped while loading in order to pack the rice. Then, the case set cap was inserted into the loaded XM232 body. A bead of acetone was applied at the joint of the cap and body sidewall. Following acetone bonding, the cases were allowed to dry at least 24 hrs before compression testing.

The six light weight cases used for drop testing were loaded differently than those described previously. These cases were filled with a combination of 3.5 lb rice and 1.5 lb gravel. The gravel and rice were placed in a 1 gal container and intermixed before adding to the XM232 case. The case cap was then acetone bonded in the normal manner. After the 24 hr drying period, these cases were additionally fastened by tying a string through the center core. The string was anchored at each end by threading it through a rubber stopper and tying it to a cross rod. The rubber stopper and rod both fit within the case depression and simulated the effect of tied igniter bags.

## **Radial Compression Test**

Twenty-five of the normal production case sets and three of the light weight case sets were used for this test. Radial compression tests were carried out with the Instron apparatus. The test case was placed between steel plate fixtures as shown in figure 1. The upper plate and Instron crosshead were moved downward onto the test case until a force of 1 lb was applied. At this point, the gage length was set to zero. Next, the crosshead was moved downward at a speed of 0.1 in./min until the total travel distance was 0.138 in. (3.5 mm). The peak load, in pounds, which occurred during this downward travel was recorded.

## **Axial Compression Test**

Twenty-five of the normal production case sets and three of the light weight case sets were used for this test. Axial compression tests were carried out with the Instron apparatus. The test case was placed between steel plate fixtures as shown in figure 2. The upper plate and Instron crosshead were moved downward onto the test case until a force of 1 lb was applied. At this point, the gage length was set to zero. Next, the crosshead was moved downward at a speed of 0.1 in./min until the total travel distance was 0.0787 in. (2 mm). The peak load, in pounds, which occurred during this downward travel was recorded.

## **Drop Test**

Six light weight cases were used for drop testing. Three cases were used for a straight drop and three for an angle drop. In the straight drop, the case was held closed end down, parallel to the concrete floor and at a height of 7 ft above the floor. The case was allowed to fall freely to the floor and the resulting damage recorded. In the angle drop test, the case was held closed end down, at an angle of 45 deg to the concrete floor and at a height of 7 ft above the floor. The case was allowed to fall freely to the floor and the observed damage was recorded.

In addition to the light weight cases, several normal weight cases were used for drop testing. Following the radial compression test, the case sets were used for straight and angle drop testing. The axial compression test cases were damaged and not usable for drop testing.

## **Density**

Densities of six light weight and six normal weight case sets were determined by measuring specimens from body sidewall, body closed end, and cap locations.

# **RESULTS**

## **Radial Compression**

Radial compression test data for normal weight cases are given in table 1. A plot of peak load versus combined body/cap weight data for the maximum 3.5 mm extension is shown in figure 3. The combination of body/cap weight was chosen for the data plot since the body and cap were the only load bearing components in the radial compression test. The combined body/cap weight range was 275.8 to 285.4 g. The current production weight specification for the trimmed body/cap combination is  $280 \pm 25$  g. Analysis of combined body/cap data and peak load data by a Shapiro-Wilk's test indicated that both data sets are normally distributed.

## **Axial Compression**

Axial compression test data for normal weight cases are given in table 2. A plot of peak load versus body weight data for the maximum 2-mm extension is shown in figure 4. Body component weight was chosen for this plot since the load is supported by only the body component in the axial compression test. Trimmed body component weight range was 202.4 to 213.2 g. The current production weight specification for trimmed body components is  $210 \pm 15$  g. Analysis of body component and peak load data by a Shapiro-Wilk's test indicated that both data sets are normally distributed.



## **Compression - Light Weight Cases**

Radial and axial compression test data for light weight cases are given in table 3. The data are also shown graphically in figures 3 and 4, respectively.

## **Drop Test**

Case component weight data and results for cases used in the rough handling drop tests are given in table 4. Light weight cases passed the straight drop test, but failed the angle drop test.

There were no failures in the straight or angle drop tests for the normal weight cases which were tested following radial compression. It should also be noted that the weight loading for these cases (4.1 lb rice) was slightly lower than the weight loading for the light weight cases (5.0 lb rice/gravel).

## **Density**

Density data are given in table 5. The lighter weight cases had densities 16 to 20% lower than normal weight cases. Caps for both light and normal weight cases had densities approximately 12% higher than their respective body components.

## **DISCUSSION**

The XM232 case easily met the proposed radial and axial compression strength requirements for the autoloader system. Data for the light weight cases showed that both radial and axial compression strength are significantly reduced when case density is decreased. Therefore, the strength characteristics should be reevaluated if any adjustments to case density are made.

Rough handling drop test data showed that light weight cases pass the straight drop, but fail the angle drop. In the angle drop, failure occurred at the closed end radius. The impact created separations large enough to permit release of both rice and gravel. This radius appears to be a weak point and its strength should be improved if lighter cases are manufactured.

## **CONCLUSIONS**

### **Normal Weight Results**

The XM232 charge has passed rough handling tests, both individually and in packed form. This series of tests was conducted to see if the XM232 case meets the

proposed radial and axial compression strength requirements for autoloader use. To reflect gravitational acceleration, the compression strength requirements were revised to:

- Radial - maximum deformation of 3.5 mm under a load of 700 N (160.5 lb)
- Axial - less than 2 mm deformation under a load of 400 N (91.67 lb)

### **Light Weight Results**

The light weight XM232 cases were specially fabricated for this series of tests. These light weight cases passed the rough handling straight drop test, but failed the rough handling angle drop test.

### **RECOMMENDATION**

The XM232 case, as currently manufactured, can withstand a radial compression load of 700 N (160.5 lb) with less than 3.5 mm deformation and an axial compression load of 400 N (91.67 lb) with less than 2 mm deformation.

If lighter weight XM232 cases are manufactured, the strength of the closed end radius will need to be improved in order to meet rough handling angle drop test requirements.

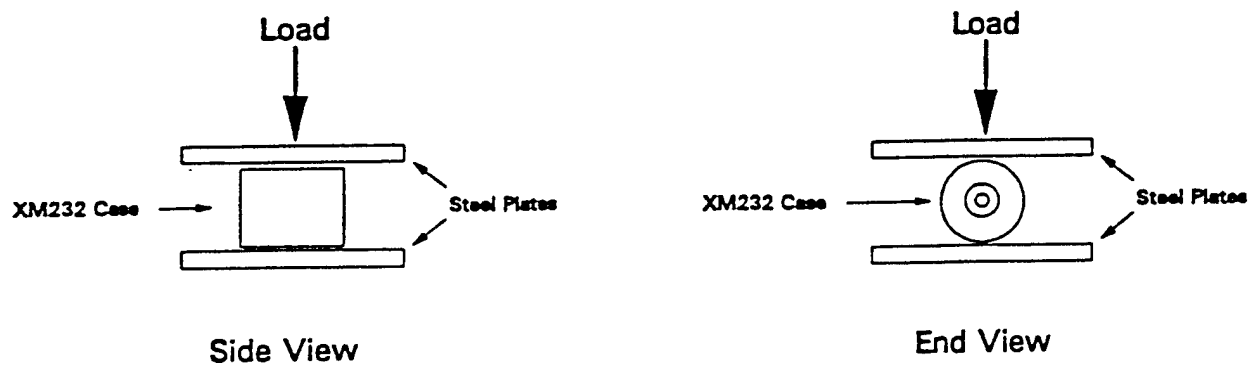


Figure 1  
Radial compression test for XM232 case

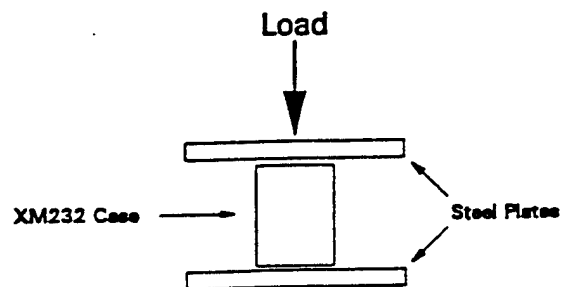


Figure 2  
Axial compression test for XM232 case

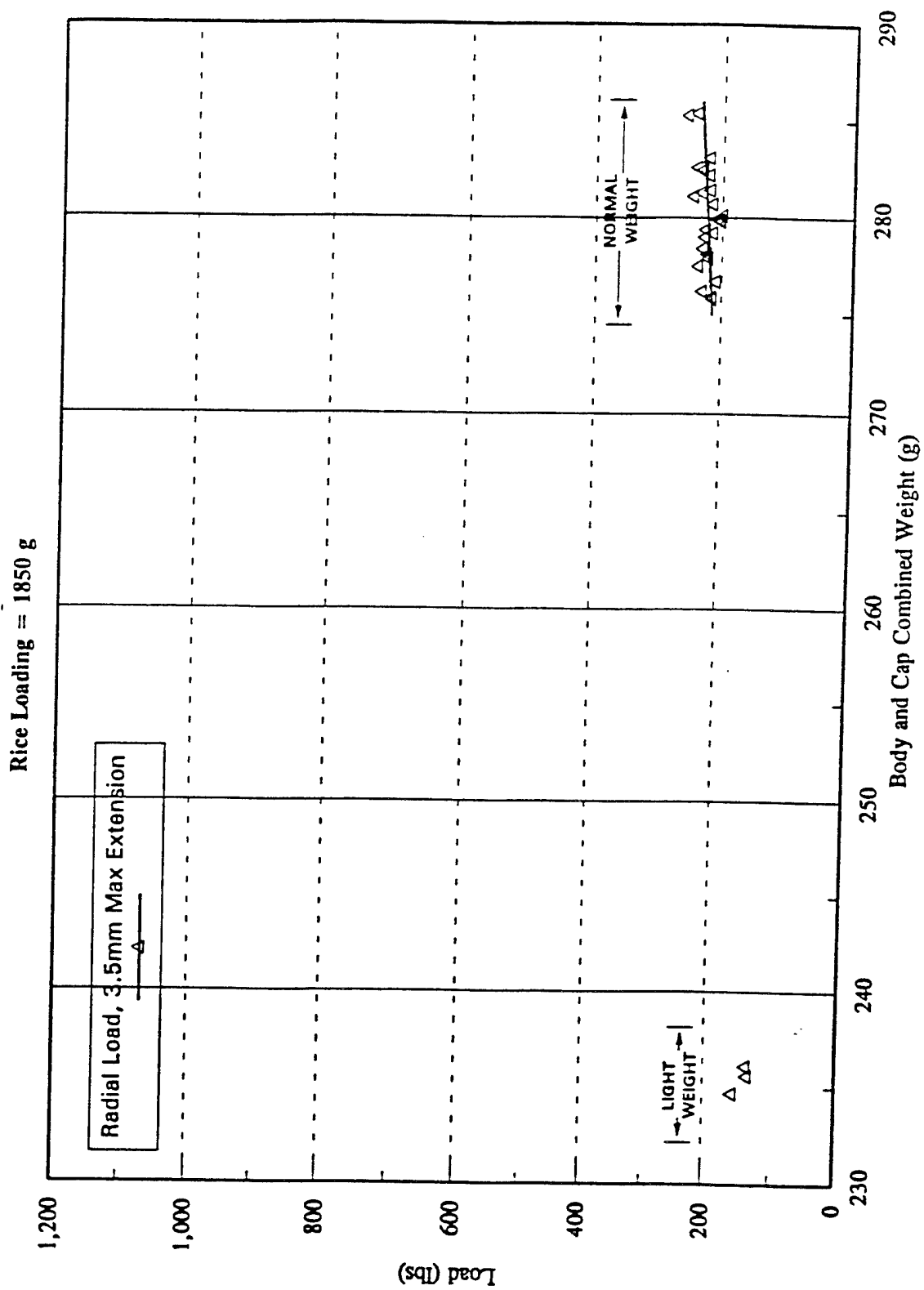


Figure 3  
XM232 case radial compression test data

Rice Loading = 1850 g

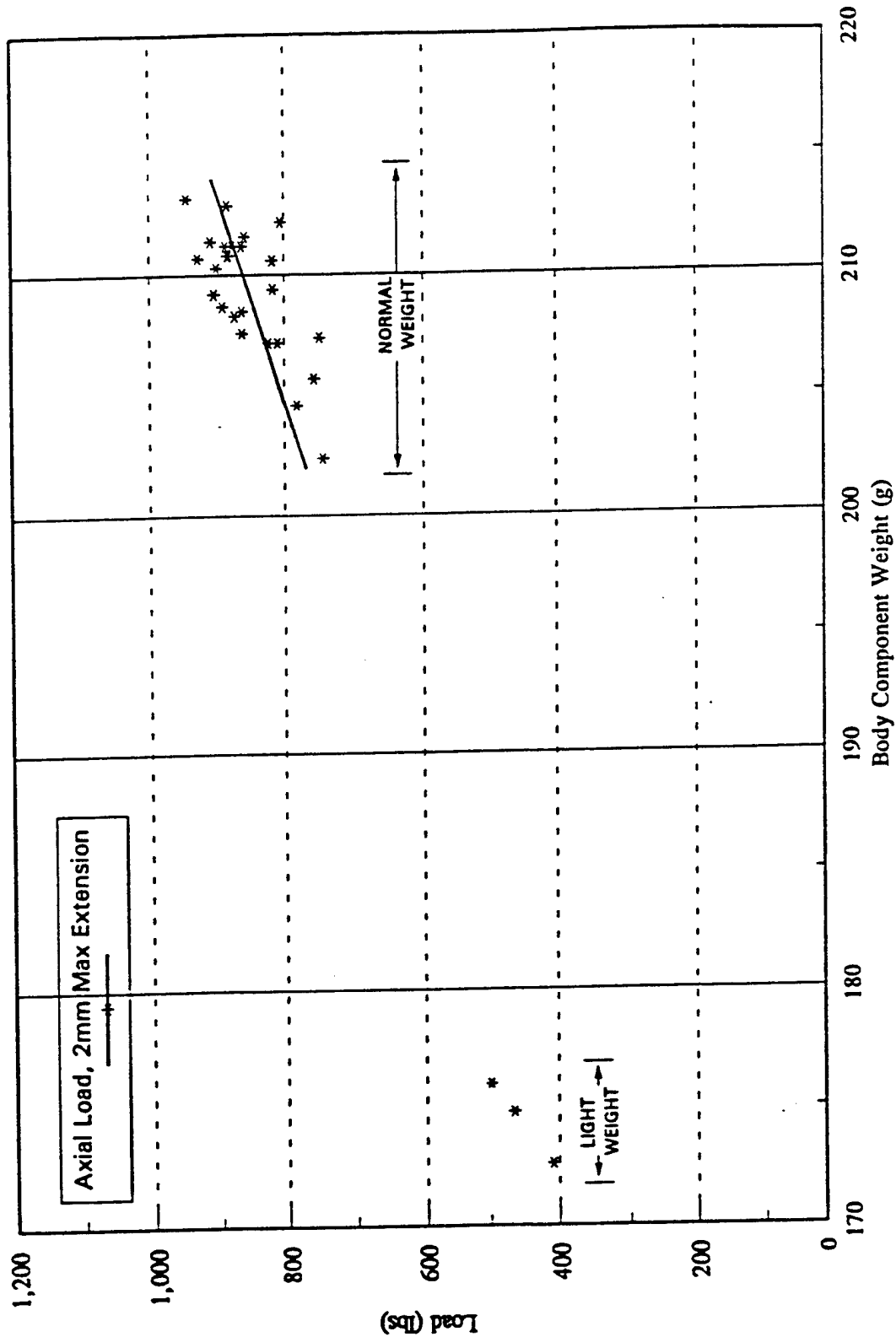


Figure 4  
XM232 case axial compression test data

Table 1  
Radial compression test data

**NORMAL WEIGHT CASES**

Body Batch # 90516  
Cap Batch # 90516  
Core Batch # 62403

<u>Case Set #</u>	<u>Cap Wt (g)</u>	<u>Body Wt (g)</u>	<u>Core Wt (g)</u>	<u>Body + Cap Wt (g)</u>	<u>Peak Load (lbs)</u>
B - 1	71.0	207.1	18.0	278.1	221.5
2	71.6	207.4	18.4	279.0	226.1
3	69.9	212.3	18.2	282.2	219.9
4	69.7	206.2	18.3	275.9	214.0
5	69.9	213.2	18.2	283.1	219.9
6	72.6	212.7	18.1	285.3	254.8
7	71.6	207.6	18.1	279.2	213.7
8	70.9	208.9	18.4	279.8	201.1
9	71.4	209.9	18.6	281.3	231.4
10	68.4	207.8	17.9	276.2	229.0
11	71.7	207.7	18.9	279.4	224.4
12	71.9	205.6	18.4	277.5	235.4
13	71.1	211.4	18.2	282.5	229.3
14	71.4	207.0	18.0	278.4	229.0
15	71.6	208.5	17.8	280.1	198.9
16	70.8	207.1	18.1	277.9	219.3
17	70.5	212.1	17.8	282.6	238.7
18	70.2	205.6	18.4	275.8	213.2
19	72.6	207.3	18.1	279.9	202.7
20	70.4	206.3	17.9	276.7	208.1
21	72.4	208.3	17.6	280.7	214.0
22	71.6	209.5	18.2	281.1	244.3
23	71.0	214.4	18.2	285.4	240.0
24	70.0	209.9	18.2	279.9	207.5
25	71.4	210.0	17.8	281.4	218.3
<u>Range</u>				275.8 - 285.4	198.9 - 254.8
<u>Average</u>				280.0	222.2
<u>Standard Deviation</u>				2.6	13.7

Table 2  
Axial compression test data

**NORMAL WEIGHT CASES**

Body Batch # 90516  
Cap Batch # 90516  
Core Batch # 62403

<u>Case Set #</u>	<u>Cap Wt (g)</u>	<u>Core Wt (g)</u>	<u>Body Wt (g)</u>	<u>Peak Load (lbs)</u>
A - 1	71.5	18.2	209.4	817.2
2	67.3	18.0	211.4	909.8
3	71.3	18.6	210.8	885.1
4	71.3	17.7	212.2	805.6
5	72.0	18.1	211.2	888.1
6	71.3	18.2	210.3	901.5
7	72.2	18.3	211.2	877.6
8	72.0	17.8	210.8	883.2
9	71.1	18.1	205.7	756.8
10	70.8	18.5	207.4	748.5
11	70.0	18.1	209.2	905.2
12	71.7	18.1	211.6	859.3
13	69.8	17.8	211.2	863.6
14	70.9	18.2	210.7	928.9
15	72.7	18.0	202.4	744.2
16	69.8	17.4	208.3	874.1
17	71.5	18.2	208.7	892.4
18	70.5	17.8	207.6	863.1
19	71.5	18.3	204.6	781.8
20	71.1	18.5	210.6	817.7
21	70.0	17.9	213.2	945.5
22	68.7	18.3	212.9	884.8
23	71.6	18.3	207.2	809.7
24	71.5	18.3	208.5	863.4
25	72.1	17.8	207.2	823.9
<u>Range</u>			202.4 - 213.2	744.2 - 945.5
<u>Average</u>			209.4	853.2
<u>Standard Deviation</u>			2.6	54.5

Table 3  
Radial and axial compression test data

LIGHT WEIGHT CASES

Body Batch # 90517  
Cap Batch # 90517  
Core Batch # 62402

Test	Case Set #	Cap Wt (g)	Core Wt (g)	Body Wt (g)	Body + Cap Wt (g)	Peak Load (lbs)
Axial	C - 1	58.8	17.9	172.6	---	408.3
Axial	2	59.5	18.5	174.8	---	462.8
Axial	3	59.2	18.6	176	---	498.3
Range				172.6 - 176.0		
Average				174.5		
Standard Deviation				1.4		
Radial	4	59.2	18.6	175.5	234.7	155.4
Radial	5	59.4	18	176.7	236.1	135.3
Radial	6	58.9	18.5	176.7	235.6	133.2
Range				234.7 - 236.1		
Average				235.5		
Standard Deviation				0.6		



Table 4  
Rough handling drop test data

LIGHT WEIGHT CASES

Body Batch # 90517  
Cap Batch # 90517 & 90520  
Core Batch # 62402

Drop Test	Case Set #	Cap Wt (g)	Body Wt (g)	Core Wt (g)	Assembly Wt (g)	Results
Straight	D - 1	59.0	172.8	18.5	250.3	Pass
Straight	2	58.6	176.3	18.6	253.5	Pass
Straight	3	59.4	173.9	18.7	252.0	Pass
Angle	4	59.4	174.1	18.8	252.3	Fail
Angle	5	59.4	175.1	18.2	252.7	Fail
Angle	6	58.9	173.8	18.6	251.3	Fail
<u>Range</u>					250.3 - 253.5	
<u>Average</u>					252.0	
<u>Standard Deviation</u>					1.0	

Table 5  
XM232 case density  
Normal weight versus light weight cases

**Normal Weight  
Sidewall Specimens**

Sample #	Density (g/cc)
B- 2 -S1	0.940
-S2	0.960
-S3	0.946
-S4	0.980
B- 12 -S1	0.928
-S2	0.933
-S3	0.958
-S4	0.932
B- 15 -S1	0.946
-S2	0.981
-S3	0.946
-S4	0.980
B- 22 -S1	0.989
-S2	0.972
-S3	0.987
-S4	0.954
B- 24 -S1	0.936
-S2	0.950
-S3	0.965
-S4	0.958
B- 25 -S1	0.958
-S2	0.921
-S3	0.965
-S4	0.958

Range 0.921 - 0.981  
Average 0.953  
Standard Deviation 0.015

**Light Weight  
Sidewall Specimens**

Sample #	Density (g/cc)
D- 1 -S1	0.779
-S2	0.777
-S3	0.783
-S4	0.809
D- 2 -S1	0.788
-S2	0.804
-S3	0.806
-S4	0.806
D- 3 -S1	0.788
-S2	0.797
-S3	0.789
-S4	0.783
D- 4 -S1	0.786
-S2	0.779
-S3	0.800
-S4	0.792
D- 5 -S1	0.803
-S2	0.800
-S3	0.778
-S4	0.812
D- 6 -S1	0.791
-S2	0.813
-S3	0.781
-S4	0.792

Range 0.769 - 0.813  
Average 0.793  
Standard Deviation 0.012

**Normal Weight  
Case Bottom Specimens**

Sample #	Density (g/cc)
B- 2 -B1	0.948
-B2	0.946
B- 12 -B1	0.952
-B2	0.955
B- 15 -B1	0.938
-B2	0.928
B- 22 -B1	0.905
-B2	0.970
B- 24 -B1	0.986
-B2	0.988
B- 25 -B1	1.000
-B2	0.997

Range 0.928 - 1.000  
Average 0.968  
Standard Deviation 0.025

**Light Weight  
Case Bottom Specimens**

Sample #	Density (g/cc)
D- 1 -B1	0.780
-B2	0.756
D- 2 -B1	0.788
-B2	0.783
D- 3 -B1	0.752
-B2	0.780
D- 4 -B1	0.804
-B2	0.811
D- 5 -B1	0.782
-B2	0.772
D- 6 -B1	0.785
-B2	0.775

Range 0.752 - 0.811  
Average 0.774  
Standard Deviation 0.018

**Normal Weight  
Cap Specimens**

Sample #	Density (g/cc)
B- 2 -C1	1.075
-C2	1.057
B- 12 -C1	1.088
-C2	1.085
B- 15 -C1	1.079
-C2	1.058
B- 22 -C1	1.058
-C2	1.058
B- 24 -C1	1.035
-C2	1.032
B- 25 -C1	1.078
-C2	1.081

Range 1.032 - 1.088  
Average 1.067  
Standard Deviation 0.020

**Light Weight  
Cap Specimens**

Sample #	Density (g/cc)
D- 1 -C1	0.871
-C2	0.868
D- 2 -C1	0.864
-C2	0.858
D- 3 -C1	0.899
-C2	0.891
D- 4 -C1	0.915
-C2	0.912
D- 5 -C1	0.910
-C2	0.901
D- 6 -C1	0.877
-C2	0.856

Range 0.855 - 0.915  
Average 0.885  
Standard Deviation 0.021

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